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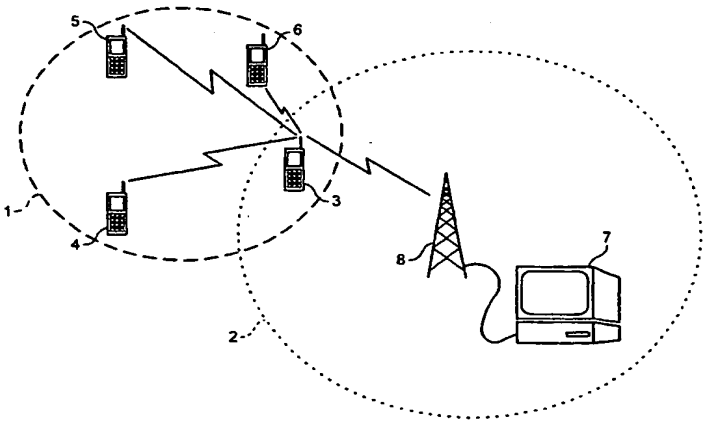

(57) Abstract: A mobile radio unit (3) operating in a direct mode network (1) of a TETRA (TErrestrial Trunked RAdio) network collects data from mobile radio units (4 to 6) also operating in the direct mode network (1) and, when it has received a predetermined quantity of data, or a predetermined time period has expired, it tunes automatically to the frequency of a base station (8) of the trunked network (2) of the TETRA network and listens for valid signals signifying that it is in operational range of the trunked system (2). Upon detecting the trunked network (2), the mobile radio unit (3) attempts to synchronise to a base station (8) and makes a call request to the trunked system (2) (i.e. to a despatcher (7)) via the base station (8). If the call request is accepted, the mobile radio unit (3) transfers the data it has collected to the despatcher (7) and once the data transfer is completed successfully, returns automatically to operation in the direct mode network (1) (e.g. by tuning automatically to the frequency of the direct mode network (1)), and continues to receive and store data from the mobile radio units (4 to 6), until, e.g., it is time to send further data to the despatcher (7).

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Mobile Radio Communications

The present invention relates to the field of mobile radio communications.

Mobile radio communications systems typically comprise a radio network which facilitates radio communication by mobile radio units capable of using the network with other mobile radio units of the network and/or other terminal units capable of accessing the network such as landline telephones. A mobile radio network will typically comprise a fixed radio infrastructure comprising one or more linked base stations arranged in a cellular fashion. However, the network could also consist of a group of mobile radio units which are communicating with each other directly, and independently of any fixed radio infrastructure, such as a TETRA (TErrestrial Trunked RAdio) Direct Mode network.

It is common for different mobile radio networks to exist in the same geographical area, i.e. to overlap with each other. For example there may be two or more private mobile radio networks (such as a police network and an ambulance network) co-existing in the same area. There could also be an overlapping public access system, such as a GSM (Global System for Mobile communications) cellular telephone network. In another case, a TETRA Direct Mode network can overlap with a TETRA trunked mode network.

Each mobile radio network will usually differ from other networks in respect of some of its characteristics, such as its transmitting frequencies, operating protocols, and/or information encoding techniques, encryption keys etc., such that a mobile radio unit set up to operate in one network will not be capable of operating in another network at its settings for the first network. However, the mobile radio unit

may be arranged so that a user can manually switch between networks, for example, by manually adjusting the operating frequency of the mobile radio unit. In other cases, the user may switch between different operating standards, such as between GSM/PCS (Personal Communication System), GSM/DECT (Digital Enhanced Cordless Telephony) and TETRA trunked mode/TETRA direct mode. However, in the normal course, a given mobile radio unit will only be registered as operating in, and/or only be able to transmit or receive calls in, one network at any one time.

Switching the network to be used by a mobile radio unit may be carried out for a variety of reasons. For example, switching may be initiated by a user for reasons of reception loss or call cost for GSM/Inmarsat mobile units. Alternatively, a user may simply wish to switch from communication in one private communications network, such as that for the ambulance service, to another, such as that for the police. Switching between TETRA trunked mode and direct mode networks may be carried out by the user because of loss of call coverage from one network or a need to access services not provided by one or other of the networks.

According to a first aspect of the present invention there is provided a mobile radio unit capable of operation in a plurality of mobile radio communications networks, the radio unit comprising:

switching means for switching temporarily from operation in one of the networks to operation in another of the radio networks;

means for automatically making up to a predetermined number of call requests in the other network; and

means for returning the radio unit automatically to operation in the original network if all the call requests in the other network are refused or fail, or, if a call request is accepted and the call in the other

network is successfully completed, when the call in the other network has finished.

According to a second aspect of the present invention, there is provided a method of operating a mobile radio unit which is capable of operation in a plurality of mobile radio networks, comprising:

operating the mobile radio unit in a first radio network;

switching the mobile radio unit to operate and place up to a predetermined number of call requests in a second radio network; and

automatically returning the mobile radio unit to operation in the original radio network if all the call requests in the other network are refused or fail, or, if a call request is accepted and the call in the other network is successfully completed, when the call in the other network has finished.

In the present invention a mobile radio unit switches temporarily from its current radio network to make up to a predetermined number of call requests and the subsequent call (if a request is successfully accepted) in a second radio network but returns automatically to operation in its original network once the call in the second network has been successfully finished or all the call requests are refused or fail.

The Applicants have recognised that it may in certain circumstances be desirable for a mobile radio unit to switch temporarily to make a call in a second radio network, and then return automatically to its original radio network for continued operation. For example, a user may wish to transmit data to a user of a different, overlapping network, but not actually switch permanently to the other network. In another example, a mobile radio unit may need to collect data, such as an encryption key for example, from a second radio network, and then return automatically to operation in the original or first radio network (where it can, for

example, use the collected encryption key for further communication). Thus, the call to which the call request made in the second, other radio network relates would generally be specific to, and/or desired solely to be sent in, the particular second network. For example, it may relate to a particular operation in the second network, such as the transfer of data to that network, or a call to the infrastructure of that network (such that if the call cannot be placed in the second network, it would not then be placed in the original network (or a further network)). This should be contrasted with a system in which a call can be placed in any available network, and the choice of network is merely determined according to criteria separate to the call itself, e.g. cost or signal quality.

The operation of the present invention should also be contrasted with, for example, a change of network to obtain a better signal or cheaper call costs, as the mobile radio unit will not generally return to its original network on termination of the call unless this is carried out manually by a user. The present invention concerns calls automatically placed by the mobile radio unit rather than a change of network made automatically by the radio unit in response to a call being manually requested by a user. In other words, rather than a call first being placed by a user and the mobile radio unit then selecting a network in which to make a call, the mobile radio unit of the present invention may first select the other network and then itself originate a call request relating to a new or original call.

The present invention should also be contrasted with the operation of TETRA trunked mode/direct mode radio units in so-called "dual watch". A mobile unit operating in "dual watch" will operate in direct mode, but periodically switch to the trunked mode network at a time known to both the mobile unit and the terrestrial

base station, to monitor for any calls which are directed to it from the trunked network. In a system in accordance with the present invention, the mobile unit would switch from direct mode operation to place a call in the trunked network, not just to see if there is a call to be received.

It is possible that the decision to switch to the second network and make a call attempt or attempts in the second network can be user initiated. However, the network switch and call attempt or attempts is preferably activated automatically, e.g. on the occurrence of a predetermined event, such as a predetermined time period elapsing. In another example, the network switch and call attempt or attempts is initiated in response to the expiry or perceived expiry of an encryption key, particularly where, for example, encryption keys for use by a mobile radio unit are supplied via only one of the radio networks in which the mobile radio unit is capable of operating.

Indeed, in a particularly preferred embodiment, the mobile unit further comprises monitoring means for monitoring whether or not an encryption key remains valid. For example, the monitoring means may determine when an encryption key expires (e.g. when an expiry time is reached or when other mobile units in a network start to use a new encryption key) and initiate operation of the switching means and of the means for automatically making up to a predetermined number of call requests in response to expiry of the encryption key.

This has the advantage that the mobile unit can then automatically retrieve a new encryption key (by placing a call in the other network) without the need for user input. Thus, new encryption keys can be retrieved automatically from the other network when appropriate.

Automatic switching also has the advantage that the mobile unit can, for example, make a call, for example

to transmit data to other mobile units or a base station, on a network which the mobile radio unit is not currently using, without the need for any user input or control to make the call in the second network. It may, for example, be desirable for a police radio to automatically notify an ambulance radio network when a safety device such as a tilt switch indicating a possible injury to the policeman is activated, or when a particular form of alert call is made on the police network. Another situation where it may be preferable for the call in the second network to happen entirely automatically rather than only at a user's prompting, could be where a mobile radio unit has collected data whilst operating on a first radio network, which it is desired to transmit to another network.

It may be that when it is desired to make a call attempt in the second radio network (whether the switch is initiated by a user, or automatically e.g. in response to a predetermined event occurring), the mobile radio unit cannot immediately switch to operation in the second network and make a call request therein, e.g. because it may be out of range of the second network. In that case, the mobile radio unit could, for example, periodically attempt to detect the presence of the second network and when it does so, automatically switch to the second network and make the call request in the second network. Also, if its call request or requests in the second network is refused or fails, the mobile radio unit could, as discussed above, thereafter periodically, e.g. after a predetermined time period, return to the second network to attempt again to make its call, and so on, until the call is successfully placed in the second network. (As discussed above, the mobile radio unit would not attempt to place the call in the original network if it cannot do so in the second network, because the call would typically be specific to the second network alone.)

As mentioned in the above examples, the call request might relate to a call for transmitting data or retrieving an encryption key. Whilst it is also possible that the call request relates to voice call, it is thus generally preferable that the call request relates to data. The present invention is generally more suited to data calls as such calls can be made under full control of the mobile unit, i.e. the call requests can be placed by the mobile unit as and when desired as the time at which the data call is placed is less critical to a user.

However, the Applicant's have recognised particularly significant advantages when the call request relates to obtaining an encryption key. For example, the mobile radio unit may be operating in a direct mode network such as a TETRA direct mode network where there is also some coverage from a fixed network such as a TETRA trunked mode network. In such a case, it may be desirable for encryption keys to be distributed over the fixed network or TETRA trunked mode network as this has an infrastructure which can suitably control secure distribution of encryption keys. Thus, a mobile radio unit which is able to automatically switch from operation in the direct mode network to place a call request to obtain an encryption key from the fixed network ensures the use of up to date encryption keys in the direct mode network conveniently and securely.

According to a third aspect of the present invention there is therefore provided a mobile radio unit capable of operation in a plurality of mobile radio communications networks, the radio unit comprising:

means for monitoring when an encryption key used for communication in one of the radio networks may need replacing;

means for switching temporarily from operation in that radio network to operation in another radio network to retrieve a replacement encryption key from the other

network in response to the monitoring means finding that the current encryption key may need replacing; and

means for returning the radio unit automatically to operation in the original radio network after successful retrieval of the replacement encryption key or after finding that the replacement encryption key cannot or does not need to be retrieved.

According to a fourth aspect of the present invention there is provided a method of operating a mobile radio unit which is capable of operation in a plurality of mobile radio networks, comprising:

monitoring when an encryption key used for communication in one of the radio networks may need replacing;

switching temporarily from operation in that radio network to operation in another radio network to retrieve a replacement encryption key from the other network in response to the monitoring means finding that the current encryption key may need replacing; and

returning the radio unit to operation in the original radio network after successful retrieval of the replacement encryption key or after finding that the replacement encryption key cannot or does not need to be retrieved.

Thus, the mobile radio unit is able to monitor when its encryption key needs replacing, and then retrieve a new encryption key from another radio network (e.g. a TETRA trunked mode network) by switching to operation in the other network to retrieve a new encryption key. For example, the mobile unit may switch to operation in the other network and automatically make a call request in the other network to retrieve a replacement encryption key. The call request might relate to a call to the infrastructure of the other network, which can securely control the distribution of encryption keys.

As discussed above, the monitoring means can determine whether or not the encryption key needs

replacing according to an expiry time for the encryption key, or a predetermined time, passing. Alternatively, the monitoring means may determine, or receive a message indicating, that other mobile units are using a new encryption key and determine that the encryption key of the mobile unit may therefore need replacing. In this regard, the mobile unit may therefore also broadcast a message after retrieving a replacement encryption key and returning to operation in the original network, which message indicates to other mobile units that a new encryption key should be used (e.g. by transmitting identification of the retrieved encryption key).

In one preferred embodiment, the mobile unit (or monitoring means), after switching to the other network, listens for a broadcast message in the other network and determines whether or not to make a call request in the other network on the basis of the broadcast message. For example, the broadcast message may comprise an identification of an encryption key to be used in the original network and the mobile unit may only make a call request (requesting the encryption key) if the identification does not match the identification of the key it is currently using. Thus, the mobile unit is able to switch to the other network temporarily if the monitoring means finds that the encryption key may need replacing, listen for a broadcast message verifying which encryption key should be being used, and request the correct encryption key only if necessary. This has the advantage of preventing unnecessary call requests in the other network.

The mobile radio unit could make only a single call request in the second network and if that request is refused or fails, revert to its original network. However, preferably it makes up to a predetermined number greater than one, e.g. up to three, call requests in the second network if the first request or requests are refused or fail, and only reverts to its initial

network once the last (e.g. third where up to three call requests are permitted) call request has been refused or fails. Of course, if one call request is successfully accepted, the mobile radio unit will proceed with the call in the second network and then revert to its original network once the call has finished without then making any further call requests in the second network. However, if a call request is accepted, but the call fails prior to completion, preferably the mobile radio unit continues to make any remaining call requests in the second network in an attempt to complete its call successfully, rather than returning immediately to the first network.

Preferably, where call attempts in the second network have failed, the mobile unit returns to the first network and waits in that network for a predetermined time period before making further attempts to place its call in the second network.

As mentioned above, it is possible that call in the second network can be a voice call (and the mobile radio unit could record the incoming speech for future replay into the second network in that event), but the present invention is particularly advantageous where the call to the other network is to transfer data to that network, as such data transfer lends itself more readily to automated transmission. Thus, for example, the mobile radio unit could collect data while operating in one network and then automatically switch over to transfer the data via a call to the other network, e.g. when a predetermined amount of data has been collected.

Thus, according to a fifth aspect of the present invention there is provided a mobile radio unit capable of operation in a plurality of mobile radio networks, which mobile radio unit can collect data in one of the radio networks and is able to connect automatically with another of the radio networks to transfer the collected data to the other radio network.

According to a sixth aspect of the present invention, there is provided a method of operating a mobile radio unit capable of operation in a plurality of mobile radio networks, the method comprising:

the mobile radio unit collecting data in a first radio network and then connecting automatically with another of the radio networks to transfer the collected data to the other radio network.

In these aspects of the invention the mobile radio unit may attempt to connect to the second radio network on request of a user, but preferably that attempt is activated automatically by a particular event occurring, e.g. after a predetermined time period has elapsed, after a predefined quantity of data has been accumulated, or on receipt of a signal from a controller, e.g. a base station. The mobile radio unit preferably returns automatically to the first network once it has transmitted its data on the second network, where it can then resume collecting data, if desired.

The data to be transferred could be, for example, text messages, vehicle status information, or medical telemetry information. In a particularly preferred embodiment the data to be transferred is location information and in particular location information relating to the position of one or more mobile radio units. (As is known in the art, mobile radio units sometimes keep a network controller appraised of their positions.) This position information could, for example, be transmitted with data indicating the identity of the located radio and the time at which the position was valid. This latter arrangement is particularly applicable when the first and second radio networks are a TETRA direct mode network and a TETRA trunked mode network, respectively. In this case a mobile radio unit operating in the direct mode network can transfer its position data automatically to the trunked mode network when it detects that the trunked

mode network is in range.

Where data is being transferred between radio networks preferably at least one and most preferably each mobile radio unit in the first radio network (e.g. a direct mode network) is arranged to collect data, e.g. position data, from other mobile radio units operating in that network, and then transfer that data to the second network (e.g. trunked mode network). In this way, for example, position information for direct mode operating mobile radio units which may be out of range of a base station of a trunked mode network may be relayed to the trunked mode network by another direct mode mobile radio unit which is in range of a base station.

Indeed, it believed that the idea of a mobile radio unit collecting data from other mobile radio units and then transferring the data to another radio unit even if operating in the same network is advantageous in its own right. For example, it may be that data collected by a mobile radio unit or units is required by a despatcher operating on the same network, but which despatcher is frequently out of range of the mobile radio units. An example of this might be in a mountain rescue situation where a base radio unit is set up for controlling the rescue and needs to be kept informed of mobile units' positions and other data, but the rescue team might be operating mainly out of range of the rescue controller's radio unit. The rescue controller could be kept updated by each mobile radio unit transferring automatically its collected data when it detects that it is within range of the control radio unit (which could be detected e.g. by each radio unit periodically attempting to call the control radio unit, or the control radio unit periodically sending out a 'presence' message which the mobile radio units can detect).

Thus, according to a seventh aspect of the present invention there is provided a mobile radio

communications system, comprising:

plural mobile radio units, each radio unit being capable of collecting data from other mobile radio units of the system and transmitting the data to a control radio unit of the system; characterised in that:

each mobile radio unit comprises means for determining whether the control radio unit is in radio communication range, and means for attempting to transmit automatically data it has collected from the other mobile radio units to the control radio unit when it determines that the control radio unit is in range.

According to a eighth aspect of the present invention, there is provided a method operating a mobile radio unit of a mobile radio communications system, the method comprising:

the mobile radio unit collecting data from other mobile radio units of the system and transmitting the data to a control radio unit of the system; characterised in that:

the mobile radio unit determines whether the control radio unit is in radio communication range, and attempts to transmit automatically data it has collected from the other mobile radio units to the control radio unit when it determines that the control radio unit is in range.

The data transfer could also depend on other predetermined events occurring, such as any or all of the events discussed above for triggering data transfer to a second radio network, with, for example, data transmission only occurring when the control radio unit is in range and the other predetermined event(s) has occurred.

In these arrangements, each mobile radio unit that collects data preferably also sends a signal to the other mobile radio units that collect data when it has successfully transferred data to the control radio unit or second radio network. In response to this signal,

the other data collecting mobile units preferably stop attempting to transfer their data to the control radio unit or second network until some further predetermined trigger event, such as the accumulation of a new amount of data or the expiry of a time period, occurs. In other words, the triggering events for the other mobile radio units to transfer data to the control radio unit or second network are then preferably reset such that the mobile radio units will only attempt to transfer data to the control radio unit or second network when the necessary event happens again. For example, any time period or data accumulation counter triggering data transmission is reset to zero, such that data transmission will only occur after a further predetermined time period or amount of data is collected. This avoids plural mobile units providing effectively the same data to the control radio unit or second network in rapid succession.

In a particularly preferred embodiment of this arrangement, each piece of data has an associated time stamp indicating when it was valid, and whenever a radio unit transfers data to another radio unit (i.e. to a radio unit that is collecting data from other radio units), as well as transferring that data, the first radio unit also transmits a message indicating the time stamp of the last piece of data it knows to have been successfully transmitted to the target control radio unit and/or second radio network. The other radio unit can then note that any data older than the time indicated in that message has already been transferred to the control radio unit or second network, and so knows that it does not have to transfer that older data. This arrangement helps to prevent radio units that do not receive the message that data has been sent continuing to attempt to send data that has already been received by the control target radio unit and/or second radio network. It thus helps to facilitate all the

intercommunicating radio units quickly getting to know which data items have already reached the control target radio unit and/or second network.

It is believed that this arrangement is advantageous in its own right. Thus, according to a ninth aspect of the present invention there is provided a method of operating a mobile radio communications system comprising plural mobile radio units, in which system the mobile radio units transfer data between themselves and each mobile radio unit is arranged to transmit at selected moments the data it receives from the other mobile radio units to a target radio unit which collects all the data from the mobile radio units, the method comprising:

associating with each piece of data a time stamp indicating when the data was valid;

each mobile radio unit when it has transmitted the data it receives from the other mobile radio units to a target radio unit, transmitting an indication to the remaining mobile radio units that it has done so and of the time stamp of the latest piece of data transmitted to the target radio unit; wherein:

each mobile radio unit whenever it transfers data to another mobile radio unit, also transmits to that mobile radio unit a message indicating the time stamp of the latest piece of data that it knows to have been to be transferred to the target radio unit.

According to an tenth aspect of the present invention, there is provided a mobile radio unit of a mobile radio communications system, comprising:

means for collecting data from other mobile radio units of the system;

means for transmitting the data it receives from the other mobile radio units to a target radio unit of the system which collects all the data from the mobile radio units;

means for associating with each piece of data a

time stamp indicating when the data was valid;

means for transmitting an indication to the remaining mobile radio units when it has transmitted the data it receives from the other mobile radio units to the target radio unit, that it has done so, and of the time stamp of the latest piece of data transmitted to the target radio unit; and

means for, whenever it transfers data to another mobile radio unit, also transmitting to that mobile radio unit a message indicating the time stamp of the latest piece of data that it knows to have been to be transferred to the target radio unit.

In this arrangement, each mobile radio unit preferably then deletes, or at least does not transmit to the target radio unit, its stored data older than the time indicated in the time stamp indicating message.

An eleventh aspect of the present invention is a method of transferring data between a plurality of radio networks, comprising one or more mobile radio units of a first radio network collecting data from other mobile radio units of the first network, and connecting with another of the radio networks to transfer the collected data to the other radio network.

The methods in accordance with the present invention may be implemented at least partially using software e.g. computer programs. It will thus be seen that when viewed from a further aspect the present invention provides computer software specifically adapted to carry out the methods hereinabove described when installed on data processing means, and a computer program element comprising computer software code portions for performing the methods hereinabove described when the program element is run on data processing means. The invention also extends to a computer software carrier comprising such software which when used to operate a radio unit or system comprising a digital computer causes in conjunction with said

computer said system to carry out the steps of the method of the present invention. Such a computer software carrier could be a physical storage medium such as a ROM chip, CD ROM or disk, or could be a signal such as an electronic signal over wires, an optical signal or a radio signal such as to a satellite or the like.

It will further be appreciated that not all steps of the method of the invention need be carried out by computer software and thus from a further broad aspect the present invention provides computer software and such software installed on a computer software carrier for carrying out at least one of the steps of the methods set out hereinabove.

A number of embodiments of the present invention will now be described, by way of example only, and with reference to the accompanying drawing, figure 1, which is a diagrammatic illustration of two radio networks.

Figure 1 shows two radio networks. Network 1 is a TETRA direct mode network linking mobile radio units 3, 4, 5 and 6. Radio network 2 is a TETRA trunked network which includes a base station 8. A despatch operator 7 is connected to base station 8.

As discussed above, it is often desirable for a fixed network despatch operator to be kept informed of information collected in a direct mode network. However, in this example mobile radio units 4 to 6 are not in direct communication with the trunked network 2 (and thus the despatcher 7), because they are outside the radio coverage of the trunked radio network and therefore cannot transmit their data directly to the trunked network 2. They therefore instead transfer their data to mobile radio unit 3 which collects the data from the other mobile radio units 4 to 6 and, as it is in range of the trunked network 2, transfers the data it collects to the despatch operator 7 via the base station 8 of the trunked network 2. Thus mobile radio unit 3 which is within the coverage of trunked network 2

is used to communicate the data from mobile radio units 4 to 6 to the trunked network 2.

The information being collected by mobile radio unit 3 would typically be location information relating to the positions of all the mobile radio units in the direct mode network, but it could equally be other forms of data, such as text messages, vehicle status information or medical telemetry. The data transferred preferably also includes the identity of the mobile radio unit to which the data relates (e.g. the identity of the radio to which the location relates) and the time at which the data was valid.

The mobile radio unit 3 collects the data and, when it has received a predetermined quantity of data, or a predetermined time period has expired, it tunes automatically to the frequency of the base station 8 of the trunked network 2 and listens for valid signals signifying that it is in operational range of the trunked system 2. (The mobile radio unit 3 may know correct frequency in advance, or it may have to search a list of frequencies.)

Upon detecting the trunked network 2, the mobile radio unit 3 attempts to synchronise to the base station 8 and makes a call request to the trunked system 2 (i.e. to the despatcher 7) via the base station 8. If the call request is accepted, the mobile radio unit 3 transfers the data it has collected to the despatcher 7 and once the data transfer is completed successfully, returns automatically to operation in the direct mode network 1 (e.g. by tuning automatically to the frequency of the direct mode network 1), and continues to receive and store data from the mobile radio units 4 to 6, until it is time to send further data to the despatcher 7. Thus the mobile radio unit 3 periodically switches from the system it is currently using into the trunked network 2 in an attempt to detect the presence of that trunked network. When the trunked network 2 is

detected, the mobile radio unit 3 automatically makes a call request into the trunked network 2, transfers its data, and on termination of the call switches back to the direct mode network 1.

The mobile radio unit 3 can decide when to send its collection of data to the despatcher 7 on the trunked system 2 in any suitable manner. For example, it could transmit the data a predetermined time delay after it sent the last update, or after it has received a predetermined amount of (new) data from the other radios. The decision to make a call on the trunked network 2 may also be user initiated, if desired. Where the mobile radio unit 3 is not in continual range of the trunked network 2 when it wishes to transfer data, it could continue to accumulate incoming data until it returns into range of the trunked network 2.

In a particular preferred embodiment, each mobile radio unit (in the present example, i.e. each mobile radio unit 3 to 6) in the direct mode network 1 operates in the same way, i.e. collects and stores data transmitted by each of the mobile radio units in the direct mode network, and transfers that data to the trunked network 2 when it comes into range of the trunked network 2 (and the necessary event to trigger data transfer, e.g. the lapsing of a predetermined time period or the collection of a predetermined amount of data has occurred). This arrangement has the benefit of increasing the frequency with which the data is transferred to the trunked network 2, i.e. the frequency with which the despatcher can get the set of data when the direct mode mobile radio units are moving in and out of trunked network coverage independently.

As a further enhancement of this arrangement, when one member of the direct mode network 1 succeeds in sending a data update to the trunked network 2, it can send a message to the other direct mode mobile radio units advising them of its success. The other direct

mode radio units can then be arranged to no longer attempt to send a data update to the trunked network 2 until the expiry of a further time or the accumulation of a defined quantity of new data. For example, in the case of position information, there could a check to ascertain that a certain number of received positions from the other mobile radio units in the direct mode network 1 had changed from the previously communicated positions before attempting to contact the trunked network 2. This arrangement allows the mobile radio units in the direct mode network 1 to act effectively as one, thereby minimising the time spent attempting to communicate data to the trunked network 2, yet enabling the despatcher 7 in the trunked network 2 to be kept as fully informed as possible about the data held by the direct mode mobile radio units.

Another example of the invention applies to the distribution of encryption keys to mobile radio units 3, 4, 5, 6 operating, for example, in the TETRA direct mode network 1. The encryption keys (such as Static Cypher Keys (SCKs)) used by such mobile radio units 3, 4, 5, 6 may be changed periodically to improve security. However, new encryption keys are distributed in some cases, over the fixed network, i.e. the TETRA trunked network 2 via base station 8 automatically or, for example, under control of dispatch operator 7.

Mobile radio units 3, 4, 5, 6 operating in the TETRA direct mode network 1 using a first encryption key are triggered to update that encryption key from time to time. In this example, the first encryption key has an expiry time and it is at the expiry time of the key that the mobile radio unit 3, 4, 5, 6 is triggered to update the encryption key. In another example, the mobile radio unit 3, 4, 5, 6 monitors the time elapsed since starting to use the encryption key and is triggered to update the key after a predetermined elapsed time. In yet another example, the mobile radio unit 3, 4, 5, 6 is

triggered to update the encryption key if another mobile radio unit 3, 4, 5, 6 that it communicates with is using a different (i.e. probably new) encryption key or when it receives a message from another mobile radio unit 3, 4, 5, 6 indicating that a new encryption key should be used. (Such a message might comprise an identification of the encryption key that should be being used, which identification the mobile unit compares with that of the encryption key it is currently using to determine whether it is using the correct key or should update its encryption key).

On being triggered to update its encryption key, the mobile radio unit 3, 4, 5, 6 switches from operation in the TETRA direct mode network 1 to operation in the TETRA trunked mode network 2. In the example shown in Figure 1, only the mobile radio unit 3 within the coverage of the of TETRA trunked mode network 2 is able to switch to operation in the TETRA trunked mode network 2. The other mobile radio units 4, 5, 6 will try to switch to the TETRA trunked mode network 2 and, when they are unable to do so, they wait a predetermined time before re-trying. When the mobile radio units 4, 5, 6 come within the coverage area of the TETRA trunked mode network 2, the switching will be successful.

A key validity message is periodically (e.g. every 60 seconds) broadcast over the TETRA trunked mode network 2 containing a serial number, key I.D., checksum or the like identifying the currently valid encryption key. On receipt of this key validity message, the mobile radio unit 3, 4, 5, 6 checks whether or not it is using the currently valid encryption key. If the mobile radio unit 3, 4, 5, 6 is using the current encryption key, the mobile radio unit 3, 4, 5, 6 returns to operation in the TETRA direct mode network 1 and continues to use its encryption key. If the mobile radio unit 3, 4, 5, 6 is not using the current encryption key, it makes a call request to the

infrastructure of the TETRA trunked mode network 2, e.g. the dispatch controller 7, requesting the currently valid encryption key. The infrastructure of the TETRA trunked mode network 2 then forwards the currently valid encryption key to the mobile radio unit 3, 4, 5, 6, which updates its encryption key to the currently valid encryption key and switches back to operation in the TETRA direct mode network 1.

If the mobile radio unit 3, 4, 5, 6 does not receive a key validity message in the TETRA trunked mode network 2 after a predetermined time in that network 2, e.g. 3 minutes, the mobile radio unit 3, 4, 5, 6 proceeds to make a call request to the infrastructure of the TETRA trunked mode network 2 requesting the currently valid encryption key as above. This ensures that the mobile radio unit 3, 4, 5, 6 has the correct encryption key before returning to operation in the TETRA direct mode network 1. In another example, if the mobile radio unit 3, 4, 5, 6 does not receive a key validity message in the TETRA trunked mode network 2 after a predetermined time in that network 2 the mobile radio unit returns to operation in the TETRA direct mode network 1 without making a call request as, for example, the absence of a key validity message indicates that there has been no change of encryption key (e.g. in a network in which the key validity message is only broadcast after a change of encryption key).

In this example, when the mobile radio unit 3, 4, 5, 6 returns to operation in the TETRA direct mode network, it sends a message to the other mobile radio units 3, 4, 5, 6 including the identity of the new encryption key. As described above, the other mobile radio units 3, 4, 5, 6 can then compare their current encryption key with that identified in the message to determine whether or not they need to update their encryption key. In another example, the mobile radio unit 3, 4, 5, 6 that has retrieved a new encryption key

may distribute the new key to the other mobile radio units 3, 4, 5, 6 in the TETRA direct mode network 1. In this example, extra security or encryption for the distribution of the encryption key in the TETRA direct mode network 1 is desirable.

Although described above with reference to a TETRA direct mode network and a TETRA trunked mode network, the present invention is equally applicable to other forms of radio networks. Indeed, the first and second radio networks can be any such networks in which a mobile radio unit can operate, and which require a change of some form to enable the mobile radio unit to operate in each different network. Thus they could, for example, be two networks operating under the same overall standard, but at different frequencies or with different information encoding techniques, such as two private radio networks of, for example, the TETRA system. Alternatively, the networks could be networks operating under different radio standards, such as a TETRA network and a GSM network. They could also be networks operating under the same overall standard, but using different operating modes and/or operating protocols of that standard, such as a direct mode network and a trunked mode network. Indeed, as will be appreciated from the above, the invention is particularly applicable to the switching of mobile radio units between operation in a TETRA direct mode network and a TETRA trunked mode network.

Claims

1. A mobile radio unit capable of operation in a plurality of mobile radio communications networks, the radio unit comprising:

switching means for switching temporarily from operation in one of the networks to operation in another of the radio networks;

means for automatically making up to a predetermined number of call requests in the other network; and

means for returning the radio unit automatically to operation in the original network if all the call requests in the other network are refused or fail, or, if a call request is accepted and the call in the other network is successfully completed, when the call in the other network has finished.

2. The mobile radio unit of claim 1, further comprising means for waiting for a predetermined time period after all the call requests in the other network are refused or fail before making further attempts to place a call in the other network.

3. The mobile radio unit of claim 1 or claim 2, further comprising initiation means for allowing a user to initiate the operation of the switching means and of the means for automatically making up to a predetermined number of call requests in the other network.

4. The mobile radio unit of any one of the preceding claims, further comprising initiation means for initiating operation of the switching means and of the means for automatically making up to a predetermined number of call requests in the other network in response to the occurrence of a predetermined event.

5. The mobile radio unit of claim 3 or claim 4, further comprising detection means for periodically attempting to detect the presence of another network and wherein the initiation means initiates the operation of the switching means and of the means for automatically making up to a predetermined number of call requests in the other network when the detection means detects the presence of the other network.

6. The mobile radio unit of any one of claims 3 to 5, wherein the initiation means initiates operation of the switching means and of the means for automatically making up to a predetermined number of call requests in the other network on receipt of a signal from a controller of one of the mobile radio communications networks.

7. The mobile unit of any one of claims 3 to 5, further comprising monitoring means for monitoring whether or not an encryption key remains valid, which monitoring means, on determining that the encryption key has expired, causes the initiation means to initiate operation of the switching means and of the means for automatically making up to a predetermined number of call requests in the other network.

8. A mobile radio unit capable of operation in a plurality of mobile radio communications networks, the radio unit comprising:

means for monitoring when an encryption key used for communication in one of the radio networks may need replacing;

means for switching temporarily from operation in that radio network to operation in another radio network to retrieve a replacement encryption key from the other network in response to the monitoring means finding that the current encryption key may need replacing; and

means for returning the radio unit automatically to operation in the original radio network after successful retrieval of the replacement encryption key or after finding that the replacement encryption key cannot or does not need to be retrieved.

9. The mobile radio unit of claim 8, wherein the mobile radio unit retrieves the replacement key by making a call request in the other network.

10. The mobile radio unit of any one of claims 1 to 7 and 9, wherein the mobile unit (or monitoring means), after switching to the other network, listens for a broadcast message in the other network and determines whether or not to make a call request in the other network on the basis of the broadcast message.

11. The mobile radio unit of any one of claims 1 to 7, further comprising means for collecting data for transfer to the other network during the call.

12. A mobile radio unit capable of operation in a plurality of mobile radio networks, which mobile radio unit can collect data in one of the radio networks and is able to connect automatically with another of the radio networks to transfer the collected data to the other radio network.

13. The mobile radio unit of any one of claims 3 to 7, further comprising means for collecting data for transfer to another network and wherein the initiation means initiates operation of the switching means and of the means for automatically making up to a predetermined number of call requests in the other network when the means for collecting data has collected a predetermined amount of data.

14. The mobile unit of any one of claims 11 to 13, wherein the means for collecting data for transfer to another network collects location information relating to the position of one or more mobile radio units.

15. The mobile unit of claim 14, wherein the location information is transmitted with data indicating the identity of the located radio and the time at which the position was valid.

16. A mobile radio communications system, comprising:

plural mobile radio units, each radio unit being capable of collecting data from other mobile radio units of the system and transmitting the data to a control radio unit of the system; characterised in that:

each mobile radio unit comprises means for determining whether the control radio unit is in radio communication range, and means for attempting to transmit automatically data it has collected from the other mobile radio units to the control radio unit when it determines that the control radio unit is in range.

17. The mobile radio communications system of claim 16, wherein each mobile radio unit that collects data has means for sending a signal to the other mobile radio units that collect data when it has successfully transferred data to the control radio unit.

18. The mobile radio communications system of claim 17, wherein each mobile unit has means for stopping attempting to transfer their data to the control radio unit, until some further predetermined trigger event occurs, in response to the signal indicating successful transfer of data by a mobile radio unit.

19. The mobile radio communication system of claim 18, wherein the predetermined trigger event is the

accumulation of a new amount of data.

20. The mobile radio communication system of claim 18, wherein the predetermined trigger event is the expiry of a time period.

21. The mobile radio communication system of any one of claims 16 to 20, wherein each piece of data has an associated time stamp indicating when it was valid, and each mobile radio unit has means for transmitting the time stamp of the last piece of data it knows to have been successfully transmitted to the control radio unit whenever it transfers data to a radio unit collecting data.

22. The mobile radio communication system of claim 21, wherein the radio unit collecting data has means for disregarding any data having a time stamp older than the time stamp indicated by the mobile radio unit transferring the data.

23. A mobile radio unit of a mobile radio communications system, comprising:

means for collecting data from other mobile radio units of the system;

means for transmitting the data it receives from the other mobile radio units to a target radio unit of the system which collects all the data from the mobile radio units;

means for associating with each piece of data a time stamp indicating when the data was valid;

means for transmitting an indication to the remaining mobile radio units when it has transmitted the data it receives from the other mobile radio units to the target radio unit, that it has done so, and of the time stamp of the latest piece of data transmitted to the target radio unit; and

means for, whenever it transfers data to another mobile radio unit, also transmitting to that mobile radio unit a message indicating the time stamp of the latest piece of data that it knows to have been to be transferred to the target radio unit.

24. The mobile radio unit of claim 22 or claim 23, further comprising means for deleting its stored data older than the time indicated in the time stamp indicating message.

25. A method of operating a mobile radio unit which is capable of operation in a plurality of mobile radio networks, comprising:

switching the mobile radio unit from operation in one of the radio networks to operation in another of the radio networks;

automatically making up to a predetermined number of call requests in the other radio network; and

automatically returning the mobile radio unit to operation in the one radio network if all the call requests in the other network are refused or fail, or, if a call request is accepted and the call in the other network is successfully completed, when the call in the other network has finished.

26. The method of claim 25, wherein, when call attempts in the other network have failed, the mobile unit returns to the first network and waits in that network for a predetermined time period before making further attempts to place its call in the other network.

27. The method of claim 25 or claim 26, further comprising a user initiating the switching temporarily to operation in the other network and the making of a call request in the other network.

28. The method of any one of claims 25 to 27, further comprising automatically initiating the switching temporarily to operation in the other network and the making of a call request in the other network.

29. The method of claim 28, wherein initiation of the switching temporarily to operation in the other network and the making of a call request in the other network is in response to the occurrence of a predetermined event.

30. The method of claim 29, wherein the predetermined event is a predetermined time period elapsing.

31. The method of claim 30, further comprising periodically attempting to detect the presence of another network and the predetermined event is the detection of the other network.

32. The method of any one of claims 3 to 5, further comprising monitoring whether or not an encryption key remains valid and, on determining that the encryption key has expired, initiating the switching temporarily to operation in the other network and the making of call requests in the other network.

33. A method of operating a mobile radio unit which is capable of operation in a plurality of mobile radio networks, comprising:

monitoring when an encryption key used for communication in one of the radio networks may need replacing;

switching temporarily from operation in that radio network to operation in another radio network to retrieve a replacement encryption key from the other network in response to the monitoring means finding that the current encryption key may need replacing; and

returning the radio unit to operation in the

original radio network after successful retrieval of the replacement encryption key or after finding that the replacement encryption key cannot or does not need to be retrieved.

34. The mobile radio unit of claim 33, comprising retrieving the replacement key by making a call request in the other network.

35. The mobile radio unit of any one of claims 25 to 31 and 34, comprising listening after switching to the other network, for a broadcast message in the other network and determining whether or not to make a call request in the other network on the basis of the broadcast message.

36. The method of any one of claims 25 to 31, wherein data is transferred to the other network during the call.

37. The method of claim 36, further comprising collecting data for transfer to another network and wherein initiation of the switching temporarily to operation in the other network and the making of a call request in the other network occurs when a predetermined amount of data has been collected.

38. A method operating a mobile radio unit capable of operation in a plurality of mobile radio networks, the method comprising:

the mobile radio unit collecting data in a first radio network and then connecting automatically with another of the radio networks to transfer the collected data to the other radio network.

39. A method operating a mobile radio unit of a mobile radio communications system, the method comprising:

the mobile radio unit collecting data from other mobile radio units of the system and transmitting the data to a control radio unit of the system; characterised in that:

the mobile radio unit determines whether the control radio unit is in radio communication range, and attempts to transmit automatically data it has collected from the other mobile radio units to the control radio unit when it determines that the control radio unit is in range.

40. A method of operating a mobile radio communications system comprising plural mobile radio units, in which system the mobile radio units transfer data between themselves and each mobile radio unit is arranged to transmit at selected moments the data it receives from the other mobile radio units to a target radio unit which collects all the data from the mobile radio units, the method comprising:

associating with each piece of data a time stamp indicating when the data was valid;

each mobile radio unit when it has transmitted the data it receives from the other mobile radio units to a target radio unit, transmitting an indication to the remaining mobile radio units that it has done so and of the time stamp of the latest piece of data transmitted to the target radio unit; wherein:

each mobile radio unit whenever it transfers data to another mobile radio unit, also transmits to that mobile radio unit a message indicating the time stamp of the latest piece of data that it knows to have been to be transferred to the target radio unit.

41. A method of transferring data between a plurality of radio networks, comprising one or more mobile radio units of a first radio network collecting data from other mobile radio units of the first network, and

connecting with another of the radio networks to transfer the collected data to the other radio network.

42. Computer software comprising computer software code portions for performing the method of any one of claims 25 to 41 when said software is run on a computer.

43. A mobile radio unit, substantially as described with reference to any one of the accompanying drawings.

44. A method of operating a mobile radio unit substantially as described with reference to any one of the accompanying drawings.

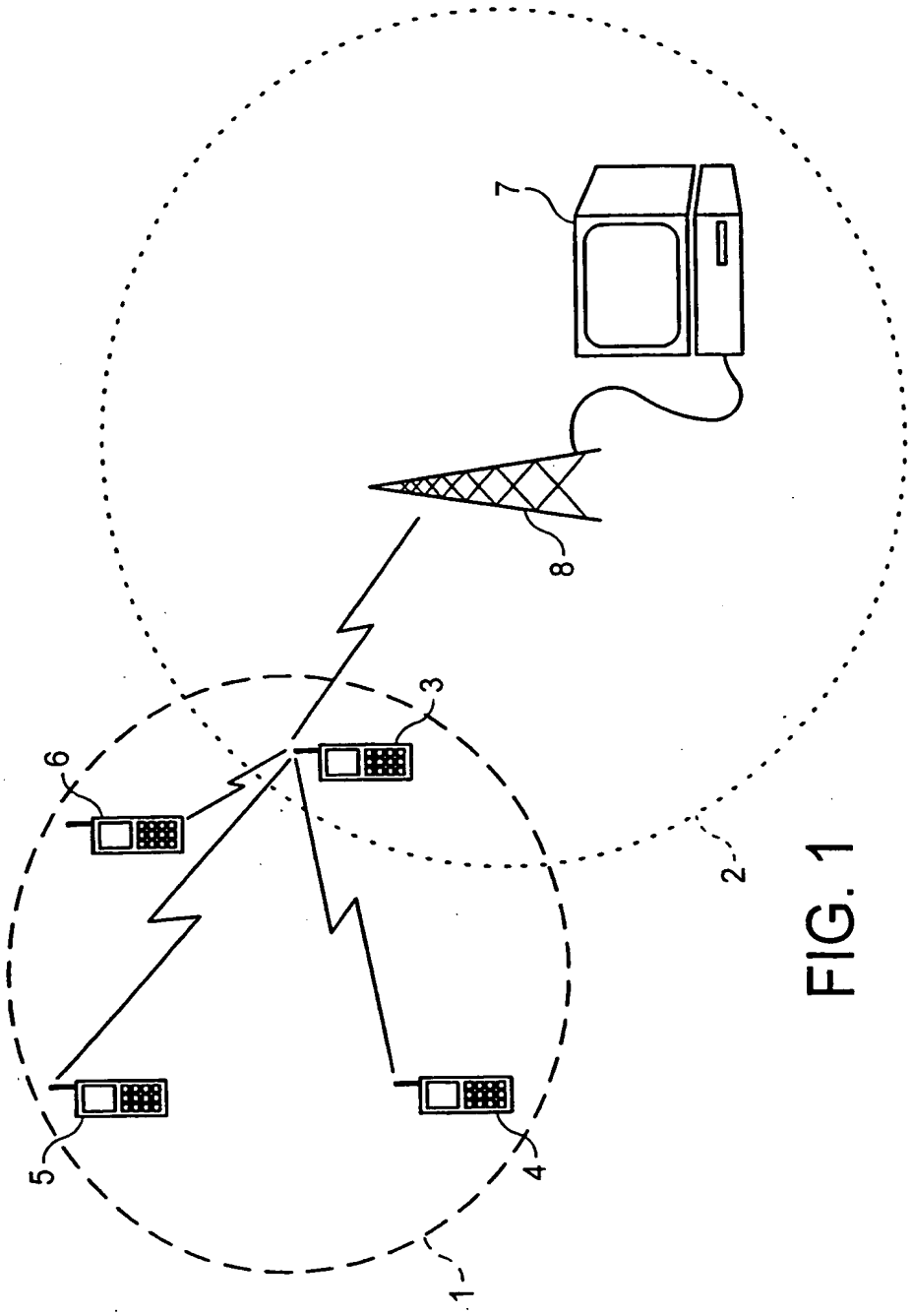

FIG. 1

INTERNATIONAL SEARCH REPORT

Int. ..ional Application No
PCT/GB 00/03648

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
WPI Data, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 218 716 A (GRUBE GARY W ET AL) 8 June 1993 (1993-06-08) column 2, line 20 - line 51 column 4, line 6 - line 67; claims 1,3; figure 2 ---	1-44
X	EP 0 663 737 A (MOTOROLA LTD) 19 July 1995 (1995-07-19) column 3, line 13 -column 6, line 1 ---	1-44
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[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

° Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
18 January 2001	24/01/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Inte .ional Application No
PCT/GB 00/03648

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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